

STUDIES OF IONOSPHERIC PLASMA ELECTRODYNAMICS

R. A. Heelis

**University of Texas at Dallas
William B. Hanson Center for Space Sciences
Richardson, TX 75083-0688**

January 1999

Final Report

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED.

20020701 068



**AIR FORCE RESEARCH LABORATORY
Space Vehicles Directorate
29 Randolph Road
AIR FORCE MATERIEL COMMAND
HANSCOM AIR FORCE BASE, MA 01731-3010**

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE 15 June 2002		3. REPORT TYPE AND DATES COVERED FINAL REPORT (SUMMARY)
4. TITLE AND SUBTITLE Studies of Ionospheric Plasma Electrodynamics			5. FUNDING NUMBERS PE: 61102F PR: 2310 TA: GL WU: AA Contract: F19628-93-K-0008	
6. AUTHOR(S) R. A. Heelis				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) University of Texas at Dallas William B. Hanson Center for Space Sciences Richardson, TX 75083-0688			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Research Laboratory/VSBXP 29 Randolph Road Hanscom AFB MA 01731-3010			10. SPONSORING/MONITORING AGENCY REPORT NUMBER AFRL-VS-TR-2002-1584	
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION AVAILABILITY STATEMENT Approved for Public Release; Distribution Unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) During the course of this contract we researched a wide variety of topics principally concerning the transport of ionospheric plasma and the role of that transport in the generation and evolution of plasma irregularities. Support from this contract has yielded a wealth of information related to the behavior of the ionosphere and its characteristics that are relevant to total electron content and the appearance of plasma structures.				
14. SUBJECT TERMS Ionospheric plasma Electrodynamics Total electron content			15. NUMBER OF PAGES	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT SAR	

STUDIES OF IONOSPHERIC PLASMA ELECTRODYNAMICS

Final Report

R.A. Heelis
William B. Hanson Center for Space Sciences
University of Texas at Dallas

During the course of this contract we researched a wide variety of topics principally concerning the transport of ionospheric plasma and the role of that transport in the generation and evolution of plasma irregularities.

Our first task was to design and implement a plasma packet tracing algorithm for determining the convective history of plasma packets subjected to motion at high latitudes due to ExB drifts. Using a convection pattern specified by the electrostatic potential distribution at high latitudes we successfully designed and implemented this algorithm that was subsequently implemented in codes run at AFRL to specify the state of the ionosphere at high latitudes.

Ultimately a time dependence was introduced into the tracing algorithm allowing the effects of spatial and temporal re-orientations of the convection pattern to be determined. Pioneering work in the formation of plasma patches from such time variations was conducted in collaboration with AFRL scientists.

The high latitude convection pattern results from contributions due to magnetic merging across the magnetopause and due to viscous interaction in the boundary layers just inside the magnetopause. Examination of extensive data sets allowed us to construct a model containing both these convection sources. The relative strength of these sources can be changed to reproduce specific observations. This model, included in ionospheric models, achieved significant success in reproducing certain ionospheric features responsible for large scale spatial gradients in the plasma.

This theoretical work was conducted in parallel with an extensive analysis of satellite observations to detect plasma patches and their associated plasma irregularities. It was found that ionization patches in the northern polar cap appear, as expected, in a universal time zone corresponding to the time when the cusp is in sunlight. At this time variations in the ionospheric convection geometry, as modeled will structure the high density plasma into large scale patches. In the southern hemisphere, the most sunward extension of the cusp leads the entire polar cap to be in sunlight and thus no contrasting density levels that constitute patches are seen. However, when the cusp crosses the terminator near dawn and dusk, conditions again become favorable for patch formation.

In studying the smaller scale plasma structures associated with patches we find that in most cases a patch is uniformly structured throughout. Patch edges have the largest magnitudes structures but these are distributed almost uniformly around the patch with almost no dependence on the direction of the plasma flow. Comparison of the appearance of plasma structures with the simultaneous appearance of structure in the convective flow suggests that plasma structuring may be caused primarily by stirring across the large scale gradient produced in the patch generation process. Finally we note that the large scintillation levels associated with ionization patches are due to the relatively high number density in the patch rather than enhanced levels of structure. Indeed we find that the level of structure defined by $\Delta N/N$ is about the same throughout the nighttime polar cap. Further work was identified to pursue under the study of scintillation and patch formation. This work related to the size distribution of patches and the shape of patches was not completed due restricted funding of the contract.

Our final area of investigation supported by this contract was in the behavior of the topside equatorial and mid-latitude ionosphere. Here we used the extensive data base from the DMSP satellites to examine the relative constituent number densities of O^+ , H^+ , and He^+ , which are dramatically dependent on solar activity and the dynamics of the F-region. We find that latitude asymmetries at the fixed DMSP altitude show quite clearly the effects of F-region neutral winds and interhemispheric plasma transport along the magnetic field lines. At solar maximum the topside ionosphere is dominated by O^+ ions and the latitudinal asymmetries in the O^+ concentration are minimized by the effects of interhemispheric transport. At the same time asymmetries in the H^+ concentrations are a

maximum. In contrast, at solar minimum H^+ dominates the topside ionosphere and latitudinal asymmetries in the H^+ concentration are minimized while O^+ latitude asymmetries are a maximum. This work shows the dramatic influence of dynamics on the distribution of topside ionospheric species and there are associated changes in the plasma temperature and total number density. Further investigation of these behaviors and the model calculations required to confirm the physical pictures that we have constructed was not accomplished due to funding restrictions.

In summary support from this contract has yielded a wealth of information related to the behavior of the ionosphere and its characteristics that are relevant to total electron content and the appearance of plasma structures. There is certainly more work to do, but this effort yielded over 20 published manuscripts and supported three Ph.D dissertations of three students who have since secured employment in research institutions.